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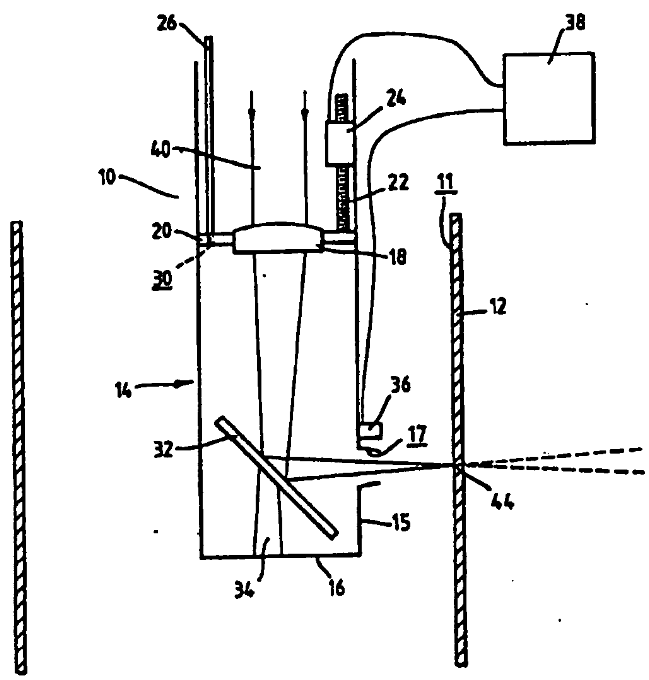
(54) **Laser beam focussing**

(57) A laser head 10 for cutting, welding or heat treating surfaces comprises a tubular housing 14 which is rotatably driven and along which a laser beam is projected with the beam axis concentric with that of the housing 14. The housing 14 incorporates a reflector 32 for reflecting the beam in a radial direction towards the surface 12 to be treated and a lens 18 for focussing the beam so that the beam has a predetermined cross-sectional area at the impingement location. A sensor 36 is provided to detect the spacing between the housing 14 and the surface 12 and the lens/reflector adjustment is made automatically to compensate for any variations in the spacing which would otherwise change the beam cross-sectional area at the impingement location. The laser head 10 can be used in long tubes e.g. for effecting circumferential cuts.



The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

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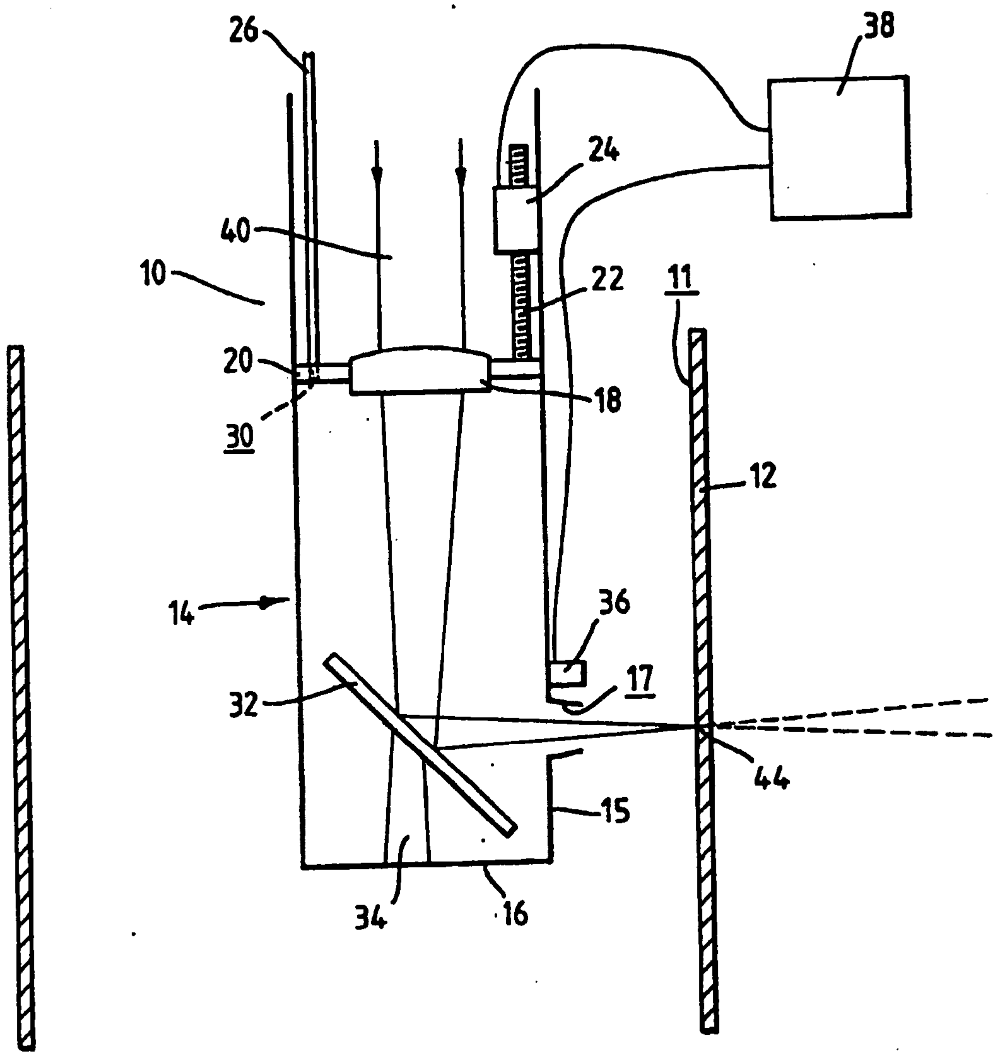
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Laser beam focussing apparatus and method

This invention relates to a method and apparatus for controlling the energy density imparted by a laser beam to a surface to be treated, especially in circumstances involving relative movement between the laser beam and the surface.

According to one aspect of the invention there is provided a method of treating a surface using a laser beam in which relative movement between the surface and the laser beam can occur, said method comprising focussing the beam towards a focal plane having a predetermined spatial relationship with the surface, traversing the beam over the surface, detecting any deviation from said predetermined spatial relationship, and optically manipulating the laser beam to substantially maintain said predetermined spatial relationship as the beam traverses the surface.

As used herein, the references to surface treatment are to be understood to include heat treatment, welding and cutting.

According to a second aspect of the invention there is provided apparatus for effecting treatment of a surface, comprising a laser beam-producing source, means for traversing the laser beam across a surface to be treated, means for directing and focussing the laser beam towards a focal plane having a predetermined spatial relationship with said surface, means for sensing any

departure from said predetermined relationship as the beam traverses said surface in use, and means, responsive to said sensing means, operable to adjust said beam focussing and directing means to substantially maintain said predetermined spatial relationship.

According to a further aspect of the invention there is provided a method of treating a surface using a laser beam in which movement between the surface and the laser beam can occur, said method comprising directing the beam towards the surface so that, at the location of impingement of the beam on said surface, the beam has a predetermined cross-sectional area, scanning the beam over the surface, monitoring a parameter affecting the beam cross-sectional area at the location of impingement, and automatically adjusting the beam to substantially maintain said predetermined cross-sectional area at said impingement location during scanning movements of the beam.

The parameters monitored may be the spacing between said surface and a datum position associated with means for directing and focussing the beam towards the surface.

According to yet another aspect of the invention there is provided apparatus for effecting treatment of a surface, comprising a laser beam-producing source, means for traversing the laser beam across a surface to be treated, means for directing and focussing the beam

towards said surface so that, at the location of impingement, the beam has a predetermined cross-sectional area, means for sensing a parameter affecting the beam cross-sectional area at said impingement location, and means, responsive to said sensing means, operable automatically to adjust the beam directing and focussing means to maintain said cross-sectional area of beam impingement substantially constant.

The sensing means may be arranged to sense the spacing of the surface relative to the apparatus and hence the position of said focal plane relative to the surface. The sensing means may comprise for example an ultrasonic sensor providing an electrical output representing the spacing of the surface with respect to a datum position associated with the apparatus. Other forms of sensor are also feasible, eg a mechanical sensor such as a spring-loaded feeler bearing against the surface.

The beam focussing and directing means may comprise a focussing element and a reflecting element arranged respectively to converge the incident beam and reflect the converging beam at an angle (eg 90°) to the axis of the incident beam, at least one of said elements being displaceable to enable the focal plane of the focussing element to be displaced relative to the axis of the incident beam.

The beam focussing and directing means is conveniently mounted within a tubular housing and the incident beam axis may be substantially coaxial with the axis of the housing.

The housing may be mounted for displacement in its lengthwise direction and/or rotatably about its axis. In one application of the invention, the apparatus is designed for insertion into the bore of a tube and the housing is rotatably and axially displaceable to enable circumferential cuts to be made in the tube by the laser beam at different points along the length of the tube.

The invention will now be further described, by way of example only, with reference to the accompanying drawing which is a diagrammatic view of a laser head.

The Figure shows a laser head 10 disposed in the bore 11 of a tube 12. The head 10 comprises a hollow cylindrical housing 14 which is closed at one end 16 and has an outlet 17 in its side wall 15 adjacent to the closed end 16. A focussing lens 18 is mounted by a support 20 within the housing 14 with its optical axis coaxial with the housing 14, the support 20 at its periphery being sealingly engaged with the inner surface of the housing 14. The support 20 is connected to one end of a lead screw 22 which is operable by a reversible drive motor 24 so that the lead screw 22 causes the lens 18/support 20 assembly to slide longitudinally within the housing 14. One end of a pipe 26 sealingly locates in an

aperture 30 in the support 20 whilst the other end is connected to a gas supply (not shown). A mirror 32 is disposed within the housing 14 at an angle of 45° to the optical axis of the lens 18, and is mounted on a support 34 which is connected to the end 16 of the housing 14. The side wall 15 is provided with a sensor device 36, such as an ultrasonic sensor, near to the outlet 17 and the device 36 is connected to a control unit 38 for controlling operation of the motor 24. A motor (not shown) is provided to move the head 10 longitudinally and rotationally with respect to the bore 11.

As shown in the Figure, a laser beam 40 from a laser source (not shown) located at the top of the housing 14 is directed coaxially along the housing 14 and, following refraction by the focussing lens 18, and reflection by the mirror 32, emerges transversely of the housing 14 through the outlet 17. The beam is brought to a focus at a predetermined point 44 relative to the inner surface of the tube 12.

In use, the head is lowered into the tube 12 and gas is introduced into the housing 14 through pipe 26 to cool the lens 18, support 20 and mirror 32. The support 20 allows a positive gas pressure to build up within the housing 14 since the only escape route for the gas is through the relatively small outlet 17. Gas escaping through the outlet 17 provides an atmosphere of the gas around the focal point 44 of the beam which is compatible

with the surface treatment, eg cutting or welding, to be carried out. The sensing device 36 provides an electrical output effectively representing the spacing between the tube 12 and the optical axis of the incident laser beam. The control unit 38 utilises the sensor output to detect any variation in the position of the focal point 44 relative to the inner surface of the tube 12 and is operable, by controlling operation of the motor 24 and lead screw 22, to position the lens 18/support 20 assembly to maintain a predetermined spatial relationship between the focal point 44 and the inner surface of the tube 12 (eg to maintain the focal point coincident with the inner surface of the tube 12) while the head 10 is moved longitudinally and/or rotationally relative to the tube 12. In this way, the control unit 38, in response to the output of the sensor 36, compensates for any irregularities in the surface of the tube 12, eg non-circularity, or lack of concentricity between the head 10 and the tube 12 during movement of the head 10 and maintains the focal point in predetermined relationship to the surface of the tube 12.

Although the apparatus is shown with only one sensing device 36 there may be several such devices 36 arranged at different positions around the housing. In use, the head 10 may be connected at or adjacent the top end of the housing 14 to a telescopic tube arrangement to facilitate the use of the head 10 within long bores. In

this case, the entire telescopic tube arrangement including the head 10, part of the arrangement or merely the head 10 may be movable, longitudinally and/or rotatably to scan the laser beam over the surface to be treated.

The head 10 need not necessarily serve to bring the laser beam to a focus coincident with the surface of the tube 12. For example, the head 10 may be used to subject the tube 12 to a heat treatment technique where a diffuse beam giving a preselected energy density at the surface to be treated is required in which event, the focal point will not be coincident with the surface. Where however the beam is used to effect welding or cutting the energy of the laser beam can be maximised at the surface by bringing the beam to a focus substantially coincident with the surface.

In the foregoing description, the focus 44 is made to coincide with the surface to be treated (or some other predetermined point where a more diffuse beam is required to impinge on the surface) by adjustment of the lens 18. In a modification, the position of the focus 44 may be adjusted by means of the mirror 32 which may be movable, by a suitable drive arrangement under the control of unit 38, lengthwise or laterally of the axis of the housing 14 so as to vary the path length between the lens 18 and the mirror reflective surface with consequent variation in the distance from the reflective surface to the focus 44.

In this event, the outlet 17 may have a slit-like configuration and positioning of the housing 14 will be co-ordinated with the movement of the mirror 14 so as to maintain the focus 44 at the desired position in the vertical direction. The mirror may also be pivotally adjustable so as to vary the angle of incidence of the laser beam on the surface.

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Claims

1. Apparatus for effecting treatment of a surface, comprising a laser beam-producing source, means for traversing the laser beam across a surface to be treated, means for directing and focussing the laser beam towards a focal plane having a predetermined spatial relationship with said surface, means for sensing any departure from said predetermined relationship as the beam traverses said surface in use, and means, responsive to said sensing means, operable to adjust said beam focussing and directing means to substantially maintain said predetermined spatial relationship.

2. Apparatus for effecting treatment of a surface, comprising a laser beam-producing source, means for traversing the laser beam across a surface to be treated, means for directing and focussing the beam towards said surface so that, at the location of impingement, the beam has a predetermined cross-sectional area, means for sensing a parameter affecting the beam cross-sectional area at said impingement location, and means, responsive to said sensing means, operable automatically to adjust the beam directing and focussing means to maintain said cross-sectional area of beam impingement substantially constant.

3. Apparatus as claimed in claim 1 or 2 in which the sensing means is arranged to sense the spacing of the

surface relative to the apparatus.

4. Apparatus as claimed in Claim 1, 2 or 3 in which the sensing means comprises an ultrasonic sensor providing an electrical output representing the spacing of the surface with respect to a datum position associated with the apparatus.

5. Apparatus as claimed in any one of Claims 1 to 4 in which the beam focussing and directing means comprises a focussing element and a reflecting element arranged respectively to converge the incident beam and reflect the converging beam at an angle to the axis of the incident beam and at least one of said elements is displaceable to enable the focal plane of the focussing element to be displaced relative to the axis of the incident beam.

6. Apparatus as claimed in Claim 5 in which the angle is 90°.

7. Apparatus as claimed in any one of claims 1 to 6 in which the beam focussing and directing means is mounted within a tubular housing so that the incident beam axis is substantially coaxial with the axis of the housing.

8. Apparatus as claimed in claim 7 in which the housing is mounted for displacement in its lengthwise direction and/or rotatably about its axis.

9. Apparatus as claimed in any one of claims 1 to 8 in which said apparatus is adapted for insertion into a bore of a tube.

10. Apparatus for effecting treatment of a surface substantially as hereinbefore described with reference to, and as shown in, the accompanying drawing.

11. A method of treating a surface using a laser beam in which relative movement between the surface and the laser beam can occur, said method comprising focussing the beam towards a focal plane having a predetermined spatial relationship with the surface, traversing the beam over the surface, detecting any deviation from said predetermined spatial relationship, and optically manipulating the laser beam to substantially maintain said predetermined spatial relationship as the beam traverses the surface.

12. A method of treating a surface using a laser beam in which movement between the surface and the laser beam can occur, said method comprising directing the beam towards the surface so that, at the location of impingement of the beam on said surface, the beam has a predetermined cross-sectional area, scanning the beam over the surface, monitoring a parameter affecting the beam cross-sectional area at the location of impingement, and automatically adjusting the beam to substantially maintain said predetermined cross-sectional area at said impingement location during scanning movements of the beam.

13. A method as claimed in claim 12 in which the parameter monitored comprises the spacing between said surface and a datum position associated with means for

directing and focussing the beam towards said surface.

14. A method as claimed in claim 11, 12 or 13 in which the laser beam is used to weld the surface.

15. A method as claimed in Claim 11, 12 or 13 in which the laser beam is used to cut the surface.

16. A method as claimed in Claim 11, 12 or 13 in which the laser beam is used to heat treat the surface.

17. A method of treating a surface using a laser beam substantially as hereinbefore described with reference to the accompanying drawing.

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